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TECHNICAL NOTE

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THE NASA PROGRAM FOR PARTICLES AND FIELDS RESEARCH IN SPACE

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SUMMARY

The early accomplishments in space are outlined with emphasis upon particle and field research. The four major groups of energetic charged particles - primary cosmic rays, energetic solar particles, the solar wind, and charged particles in geomagnetically trapped orbits near the earth are discussed and further investigation of Galactic cosmic rays, energetic solar flare particles, the solar plasma and the trapped radiation is recommended. The primary NASA launch vehicles of the present and the future are related to the experiments proposed. Some of the spacecraft planned for the future are also described.

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INTRODUCTION

During the past several years, the United States has been carrying out investigations in the various space sciences by means of earth satellites and deep space probes. The success of this program thus far is indicated by the number and the significance of the discoveries made. This space science program is, to a considerable extent, an outgrowth of the program for investigating the upper atmosphere by means of rockets and balloon-borne instrumentation. The possibility of using rockets for upper air research was recognized as early as 1919 by Dr. Robert H. Goddard (Reference 1). Plans were made early in 1932 to use Goddard's rockets during the Second Polar Year to lift small instrument payloads to heights of up to fifty miles. But these plans were interrupted by the economic depression, and it was not until after the Second World War that rockets were actually used for such research.

In October 1945, a small liquid-fueled research rocket known as the WAC-Corporal was fired with a 10-kilogram payload to an altitude of 65.5 kilometers. Soon after this, on April 16, 1946, the first captured German V-2 was launched at the White Sands Proving Ground with one of Dr. James A. Van Allen's Geiger-Müller counters in the nose section to measure the intensity of cosmic rays above the dense atmosphere. By January 1952, 68 V-2's, 63 Aerobees, and 7 Viking rockets had been fired into the high atmosphere. The rocket program continued to accelerate rapidly, and plans were made to launch a number of rockets in the U. S. part of the International Geophysical Year (IGY) program. The development of the miniaturized and highly rugged scientific instrumentation was concurrent with the development of the rockets. By 1954, this instrumentation was developed to the point where moderately complex Geiger-Müller counter arrays and scintillation detector systems were being carried in rockets having payload capabilities of only 5 to 10 kilograms.

*Originally presented at Scoula Internazionale di Fisica "Enrico Fermi", Varenna sul Lago di Como, May 23 - June 3, 1961

This work led directly to the development of the first highly complex transistor instrumentation which was developed during the years 1956-1957 for use in the early Vanguard satellites.

Following the successful launchings of the first U. S. spacecraft Explorers I, III and IV, and Vanguard I (1958α, 1958γ, 1958ϵ, and 1958β respectively) the need for an integrated national program for conducting space research was obvious, and the National Aeronautics and Space Administration (NASA) was established to formulate and carry out this task. A recent revision of the original act defines the mission of NASA in more detail.

"The administration, in order to carry out the purpose of this act shall

1. Formulate specific national objectives in space and, in the light of such objectives, develop a comprehensive program for the exploration, investigation, and utilization of space for peaceful purposes;

2. Conduct research into problems of flight within and outside the earth's atmosphere with the view to their practical solution, including research in the field of aeronautics necessary to the continued advancement of both civilian and military aviation;

3. Conduct such activities as may be required for the exploration, scientific investigation, and utilization of space for peaceful purposes, and develop space vehicles for use in such activities;

4. Arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations; and

5. Provide for the widest practicable and appropriate dissimination of information concerning the activities and the results thereof."

To summarize them briefly the specific objectives of the NASA program are threefold (Reference 2, pp 6-7):

1. "To produce scientific data on the space environment, the sun, earth and planets, and the galaxy, using unmanned spacecraft equipped with instrumentation and telemetry to relay data to the ground. This information is essential to all utilization of space and to an understanding of the physical universe and its relation to man.

2. "To study early applications of earth satellites to meteorological research and weather forecasting, long-distance wideband radio communication, navigation, and similar tasks.

3. "To explore the problems connected with the travel of man in space, at first in orbital flight around the earth for short periods, later in flights to the moon, and still later to the planets and the outer reaches of the solar system. The pace of manned exploration will be determined largely by the results obtained in the early orbital flights."

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ACCOMPLISHMENTS OF THE FIRST YEARS

With these objectives in mind, it is interesting to review the accomplishments of the early years of the U. S. program. By May 23, 1961, nine Explorer satellites, four Pioneer planetary probes, and three Vanguard satellites had been successfully launched as a part of the U. S. space science program. In addition, two Tiros satellites and an Echo satellite had been launched as a part of the earth satellite applications program to fulfil the second group of objectives listed above. And the Freedom 7 Project Mercury capsule had been launched on a ballistic trajectory as one of the first steps in the manned exploration program outlined above.

These satellites and deep space probes have already provided a large amount of information about the space environment. Of the satellites launched thus far, many have been designed primarily for investigating energetic particles and magnetic fields in space. Of those instrumented for other purposes, Vanguard I was intended primarily to study the shape of the earth, and Vanguard II (1959α) investigated the cloud cover over the earth's surface. Explorers VIII (1960ξ) and IX (1961δ) were developed to investigate the ionosphere, the density of the upper atmosphere, and passive communication techniques. Although the results obtained from the manned satellite programs and the satellites carrying other than energetic particle and magnetic field experiments are interesting and significant, they will not be discussed further in this paper.

Explorers I and III were launched February 1, and March 26, 1958 respectively. Each satellite contained a single Geiger-Müller counter having a geometric factor of approximately 17 cm^2. This counter can be seen in the mid-section of the satellite in Figure 1. In Explorer I, the Geiger-Müller tube counting rate was telemetered directly to the ground receiving stations. In Explorer III the counting rate, in addition to being telemetered directly, was also stored by a small tape recorder in the satellite and sent to the ground receiving stations on command at the completion of each orbit. The existence of the very intense geomagnetically trapped radiation now known as the Van Allen radiation was discovered with these two satellites. They provided the first rather crude survey of the spatial extent of this region of radiation (Reference 3).

Immediately following the discovery of this region of intense corpuscular flux, another satellite (Explorer IV) prepared specifically for the purpose of further defining its characteristics, was launched on July 26, 1958. It provided: (1) a more complete survey of the spatial distribution of the radiation at radial distances up to 2220 kilometers between the latitudes of $\pm 51°$ geographic; (2) a measure of the radiation intensity by detectors having several different characteristics and under various amounts of absorber, thus providing several points on the particle integral energy spectrum curve at a large number of

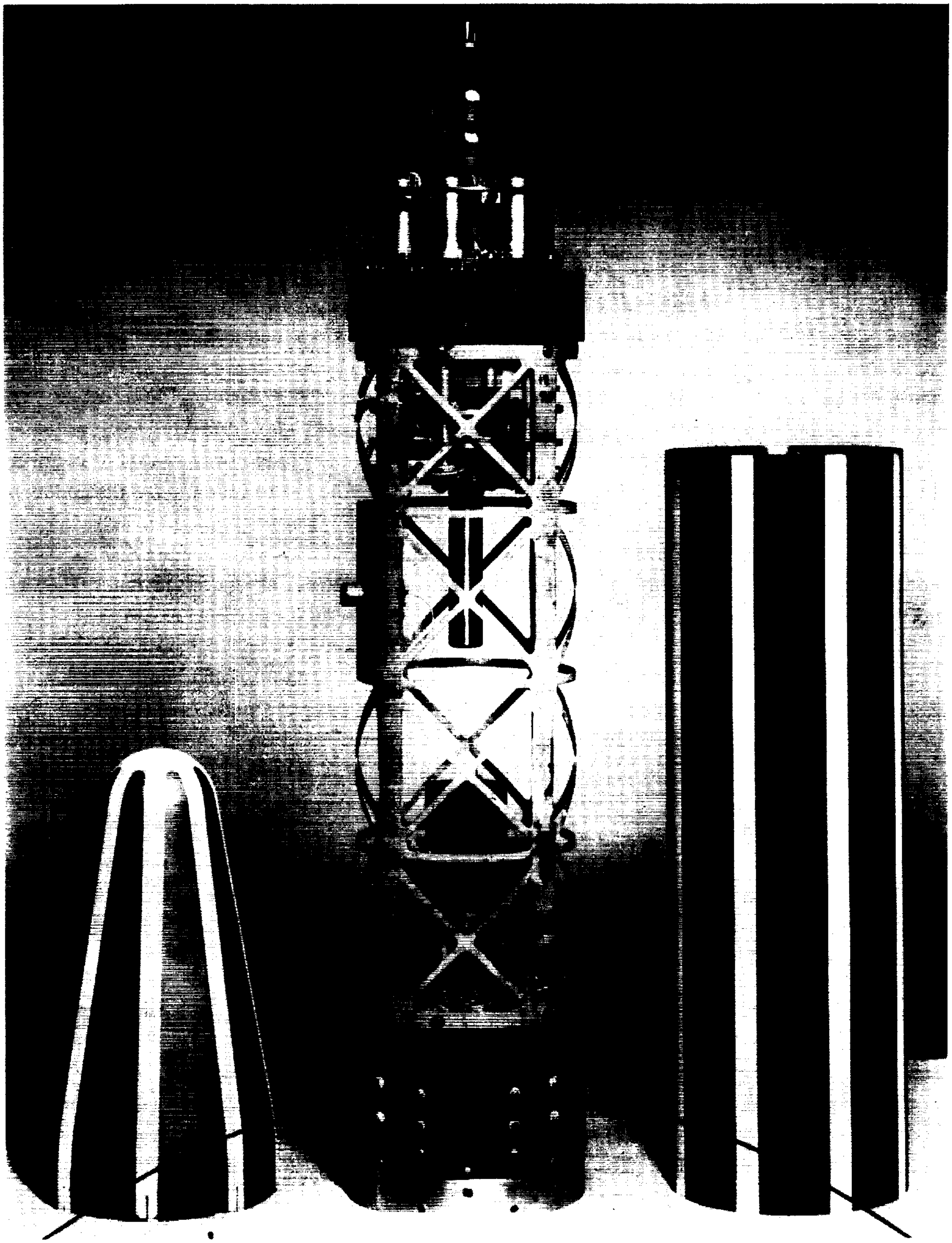

Figure 1 - The Explorer I instrumentation section

postions; (3) a rough indication of the angular distribution of the trapped particles; and (4) important information about the trapping mechanism obtained as a result of the artificial electron shells created by Project ARGUS (References 4 through 8).

The experiments described above were carried in satellites having apogee heights of less than 2500 kilometers. As a result, the configuration of the more distant regions of the Van Allen belt structure was not known. The existence of two separate belts had not been unambiguously indicated by the low altitude data, although the possibility was realized. The importance of extending the survey to a greater radial distance was obvious; therefore, radiation detectors were prepared for Pioneers I, II, III and IV. The Pioneer II launch attempt was unsuccessful. Pioneers I and III traveled to distances of about 100,000 kilometers, and the data obtained from these two spacecraft during their traversals of the radiation belt gave the first information about its radial extent (References 9, 10 and 11). Pioneer I, launched on October 11, 1958, indicated that the more intense radiation was confined to the region near the earth (Reference 12). However, it did not show the existence of the two distinct belts because of gaps in telemetry recovery. Pioneer III, launched on December 6, 1958, made two cuts through the trapping region and clearly revealed the existence of the two great belts. Pioneer IV (Figure 2), launched on March 3, 1959 into a solar orbit, further confirmed the findings of Pioneer III; and a comparison of the Pioneer IV data with those of Pioneer III showed that the intensity of the outer belt was variable and apparently related to solar activity, thus indicating the high probability of the solar origin of the particles responsible for the outer belt.

Explorer VI (1958δ), launched on August 7, 1959, contained a proportional counter array, a Geiger-Müller counter, an ionization chamber, a scintillation detector, and a simple one-axis magnetometer. The data received from this satellite indicated the existence of a toroidal current ring located in the region from 5 to 7 earth radii; and also that the magnetic field in space experiences widespread disturbances during some magnetic storms, and that changes in the particle pitch angles (angles between the direction of motion and the magnetic field lines) are followed by changes in the radiation intensity observed by a given detector. In addition, the data showed the radial motion of the peak intensity in the outer belt at these times (References 13 through 18).

Explorer VII (1959ι), launched on October 13, 1959 into a nearly circular orbit around the earth, and Pioneer V (1960α), launched on March 11, 1960 into a solar orbit, operated concurrently so that information was obtained at large radial distances at the same time that the intensity at the lower edges of the radiation belt structure was being monitored (Figures 3 and 4). Explorer VII carried two Geiger-Müller counters, one relatively unshielded and the other shielded by about 1.5 gm/cm^2 of material. Pioneer V carried a proportional counter array, a Geiger-Müller counter, an ionization chamber, and a search coil magnetometer similar to the Explorer VI instruments.

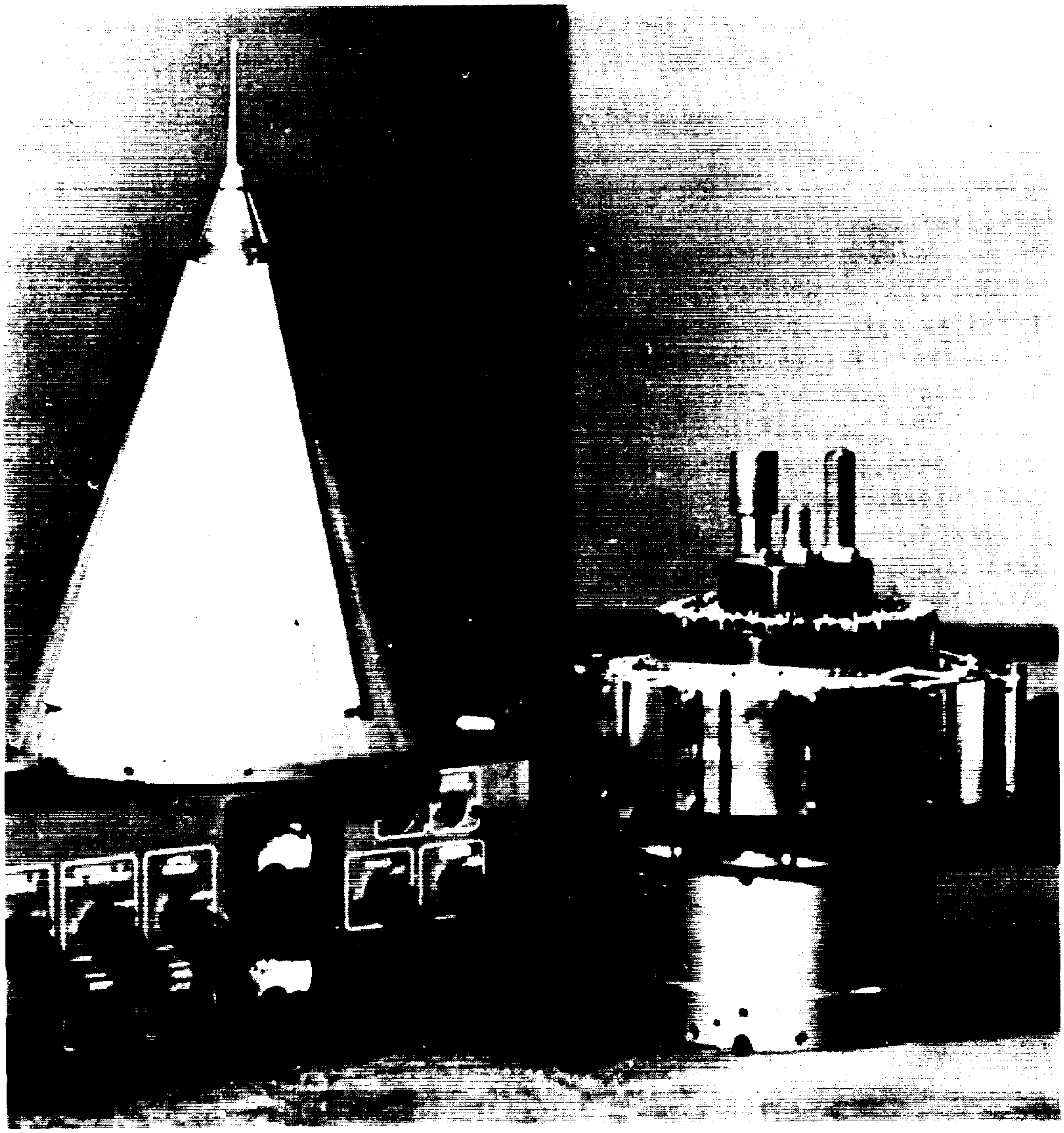

Figure 2 - The two Geiger-Müller Counters are located in the two outside vertical cylinders on the top of the Pioneer IV payload

The data from these two spacecraft provided a great amount of new information (References 19 through 30). They indicated that the Forbush decrease is widespread - with approximately the same decrease at 5×10^6 kilometers from the earth as near the earth's surface. Solar protons were detected by both Pioneer V and Explorer VII following the flare of April 1, 1960. The correlation of the Pioneer V and Explorer VII data indicate

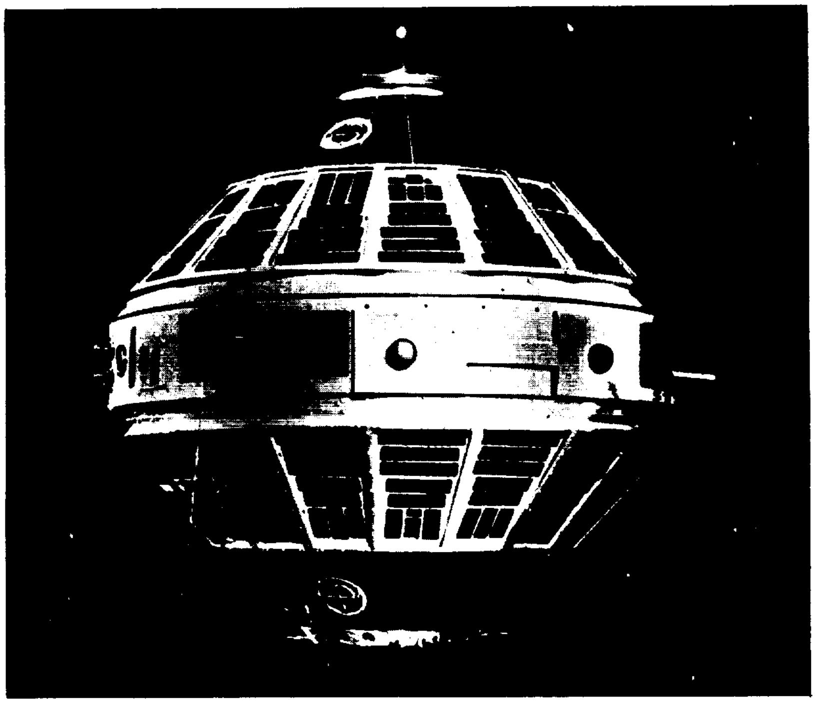

Figure 3 - Explorer VII

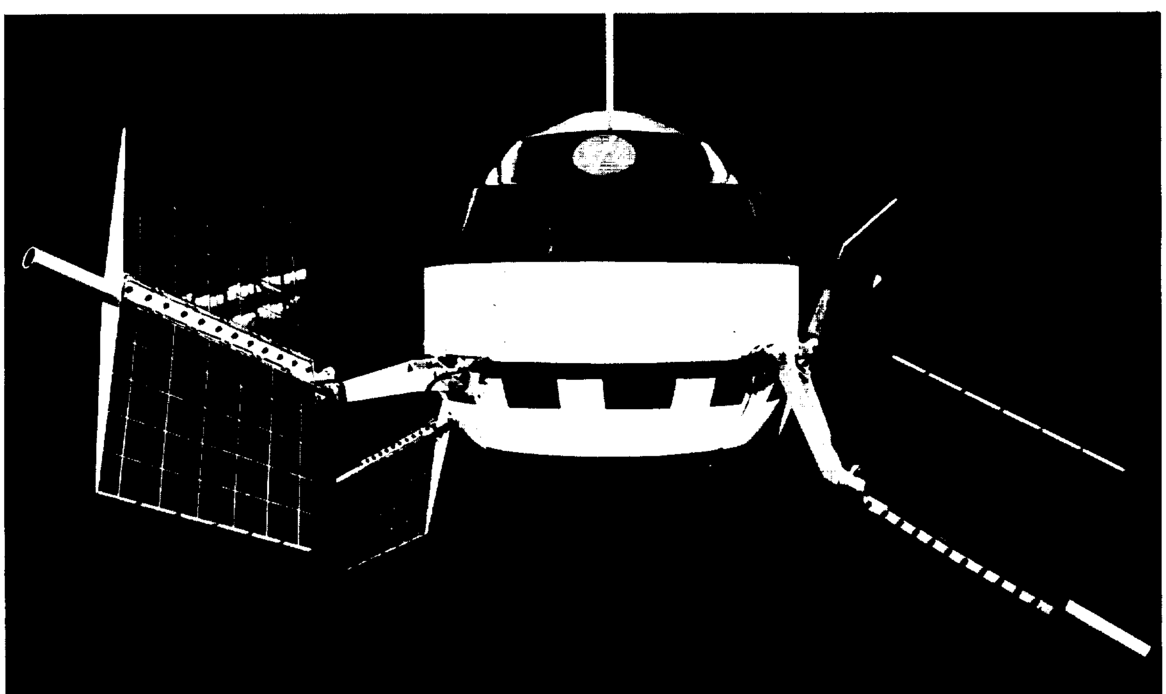

Figure 4 - Pioneer V

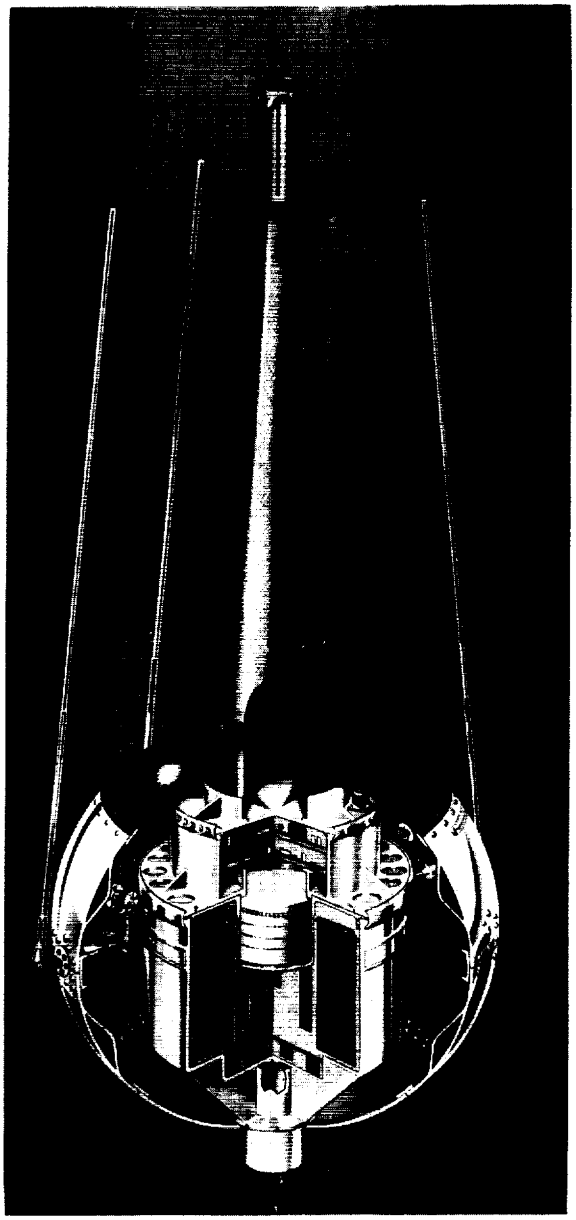

Figure 5 - Cutaway view of Vanguard III

that the electrons with energies exceeding 30 kev which were observed in the outer belt following that solar disturbance must have been locally accelerated, since a sufficiently large integrated particle flux in that energy range was not detected by Pioneer V prior to the enhancement of the outer belt intensity. In addition, Pioneer V measured the intergalactic magnetic field; the value varied from 2.7 gammas during quiet periods to a maximum of 40 gammas during magnetically disturbed periods. The counters in Explorer VII operated until March 1960 and provided much information about the radiation intensity in the lower fringes of the belt structure. They indicated the high stability of the inner belt and revealed many interesting spatial and temporal structural features of the outer belt. The ground observation of a red auroral arc (6300A) immediately below the region of the outer belt peak intensity as determined by Explorer VII following the solar event on November 28, 1959, indicated that particles being dumped from the outer belt are probably directly responsible for at least a portion of the auroral activity.

The Vanguard III (1959η) satellite, launched on September 18, 1959, carried a proton precessional magnetometer (Figure 5) which measured the magnitude of the earth's magnetic field throughout the orbit - extending from 510 to 3700 kilometers in range, and between ±33 degrees in latitude. The data from this flight, which are still being analyzed, are expected to result in an accurate mapping of the earth's magnetic field and in the production of a set of values (for the year 1959) of the 48 coefficients in the six-term expansion of the earth's magnetic field. These data indicate that the earth's magnetic field at small radial distances is highly stable.

The next addition to the family of Explorer satellites which contained magnetic field and energetic particle experiments was Explorer X (1961κ), launched on March 25, 1961.

This spacecraft (Figure 6) attained a radial distance of about 260,000 kilometers carrying an alkali vapor maser magnetometer, two flux-gate magnetometers, and a proton plasma probe covering the energy range from below 5 to 2300 electron volts. These instruments indicated that the magnitude of the interplanetary magnetic field varied between 6 and 40 gammas. Very little plasma was detected during the periods when the magnetic field was high prior to the sudden commencement which occurred near apogee. More information on both the magnetic field and the plasma is expected following the more complete analysis of the data.

Explorer XI (1961ν 1) was launched on April 27, 1961 to study the gamma rays. It carried a complex gamma ray telescope employing scintillation and Čerenkov detectors in an array designed to discriminate against charged particles and neutrons. The data are being reduced, and the results should be available in several months.

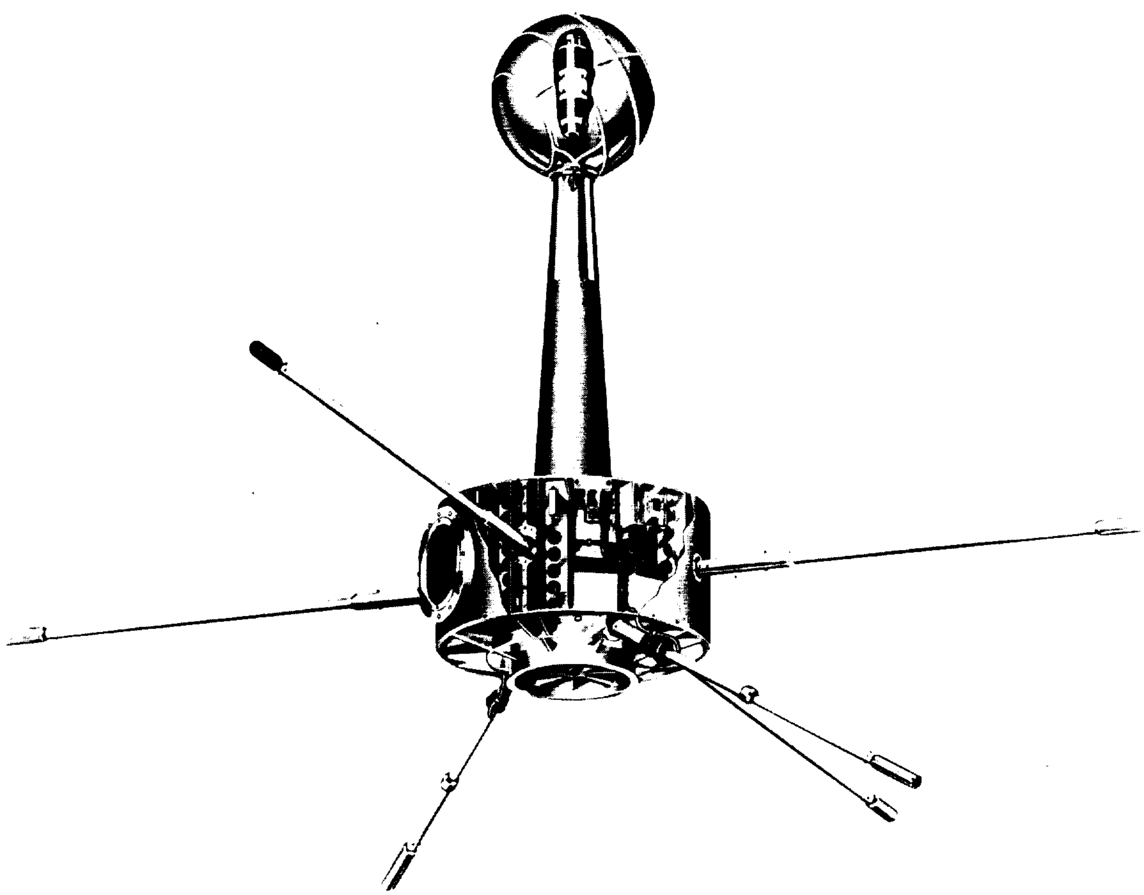

Figure 6 - Cutaway view of Explorer X

In addition to the satellites and space probes discussed above, a number of sounding rockets have been fired. Among the most recent firings were a series of solar beam experiments flown from Fort Churchill, Canada, during the September and November 1960 solar events, and a rocket flown into the lower edge of the inner Van Allen belt from the Pacific Missile Range in California. These recoverable vehicles carried nuclear emulsions for the study of the Z and energy spectra and the fluxes of the electrons and protons. The emulsions have indicated that the slope of the proton energy spectrum on the inner edge of the inner Van Allen belt depends on the latitude (Reference 31); and they have measured the energy and Z spectra of solar protons arriving at Fort Churchill following the solar flares of 3 September and 12 November 1960 (Reference 32).

FUTURE INVESTIGATIONS

Energetic charged particles can be divided into four major groups: primary cosmic rays; energetic solar particles; the solar wind; and the charged particles in magnetically trapped orbits near the earth and some of the other planets.

The primary cosmic rays arise from acceleration mechanisms occurring outside the solar system, but are modulated both in spectrum and intensity by solar system electrodynamics. In the past, cosmic rays have been studied in the atmosphere by means of high altitude rockets and balloons, as well as on the earth's surface where atmospheric effects and variations in the earth's magnetic field due to ring currents and solar plasma have caused additional modulations. The use of satellites and space probes permits the elimination of these local modulations so that the characteristics of the primary particles and of the solar-system-induced variations may be studied more quantitatively.

The second major group consists of the energetic solar particles accelerated in or near the sun on the occasion of major solar flares. The relative abundance of the elements in these streams of particles is approximately the same as in the sun. In addition to the nucleons, electrons and photons are also released during these flares. These streams of charged particles carry along their own magnetic fields which, upon approaching the earth, cause modulations of the particle fluxes reaching the earth from all external sources and of the structures in the regions of trapped radiation.

The third major category is the continuously emitted low energy solar plasma – the solar wind. This plasma consists of particles having both positive and negative charges. It produces a charged particle density in the region of the earth which is appreciably greater than that in interstellar space, and, because of its general motion outward from the sun, produces some distortion of the distant geomagnetic field and a resultant modulation of particles reaching the earth from outside the earth system.

The fourth major group is the reservoir of charged particles in magnetically trapped orbits near the earth and near at least some of the other planets. It appears at this time most probable that the electrons and protons in the earth's inner radiation belt result primarily from the decay of neutrons produced by cosmic ray interactions in the high atmosphere. Most of the particles in the outer belt probably originate at the sun, although some local acceleration mechanism very likely acts to inject the particles into their trapped paths and to produce the energy spectra observed.

From these very brief introductory remarks, it is clear that a major field of investigation has expanded explosively during the last three years as a result of the availability of vehicles capable of carrying detectors into space. This field is actually a combination of physics and astrophysics. It is aimed at direct investigation of the basic questions of particle acceleration, the generation of magnetic fields in the stars, planets, and in galactic space, and the motions of matter and magnetic fields in space. The ultimate outcome of this line of investigation should be a better understanding of a large number of broad cosmological questions such as the development and dynamics of galaxies, the distribution of matter in the galaxies, the origin of the high energy cosmic rays, and the physics of stars and planets. In order to gain this broad understanding, at least some of the following more specific investigations must be conducted in the future by means of satellites and space probes.

Galactic Cosmic Rays. In order to gain an understanding of the origin of cosmic rays and the acceleration mechanisms acting on them, it will be necessary to study:

1. The cosmic ray charge spectrum including, perhaps, the relative abundances of the various isotopes

2. The energy spectra of the constituents

3. The presence of and the energy spectra of high energy electrons, anti-matter, photons, and other particles

4. Cosmic ray variations and the relationships between these variations and other events in the solar system

5. The directional characteristics of the cosmic radiation.

It is also expected that the cosmic ray flux will continue to be used as a source of high energy particles for the study of high energy nuclear interactions and nuclear forces, and in the search for new particles.

Energetic Solar Flare Particles. In order to study the production of the energetic solar particles and the magnetic fields which are intimately associated with their production near the sun, and to study the effects of these solar particles on the geomagnetic field and the earth's atmosphere, it will be necessary to continue investigation of:

1. The relationships between the relative abundances of the various elements in the solar particle stream and in the sun itself

2. The particle fluxes as a function of time

3. The energy spectra of the various constituents, and

4. Correlations between the production of energetic solar particles and other phenomena such as visable flares, coronal streamers, solar radio noise, arrival of energetic solar particles near the earth, geomagnetic disturbances, variations in the structure of the radiation belts, and aurorae near the earth. It should be noted, however, that it will not be possible to press vigorously the investigation of these particles during the next three to six years, since these events will be rare during the approaching sunspot minimum.

Solar Plasma. To provide insight into the physical processes occurring in the sun, to study certain modulations of the primary cosmic ray flux, and to determine the nature of some features of the geomagnetic activity, it will be necessary to study the low energy plasma emanating from the sun. Therefore, investigations will be made to:

1. Determinate of the fluxes and energy spectra of all components of the solar plasma

2. Study of the variations of the solar plasma at various positions in the solar system and at various times

3. Correlate the solar plasma with other solar and geophysical phenomena.

The Trapped Radiation. In order to gain a complete understanding of the source and loss mechanisms acting on particles in the trapping regions, it will be necessary to gain a more comprehensive understanding of:

1. The energy spectra of the various constituents of the inner radiation belt as a function of position

2. The temporal characteristics of the inner belt

3. The energy spectra of the constituents of the outer belt, with especial emphasis on continuation of the investigations to much lower energies

4. The angular distributions of the various constituents of the outer belt as a function of position along the trapping lines

5. The morphology of events following solar flares and their relationships to other solar activity and geophysical phenomena.

THE LAUNCHING VEHICLES

To understand more completely the capabilities and shortcomings of the spacecraft now being used and planned for the immediate future, it is necessary to review briefly the capabilities of the vehicles which will be used to place them in orbit. In the vehicle program, and in the spacecraft program too as will be evident later, several guiding principles apply.

The NASA space science program is a civilian program and, therefore, may differ somewhat in approach from one based on military requirements. NASA is appropriated a certain finite amount of money by Congress, and it is NASA's responsibility to obtain the greatest possible return in terms of new scientific knowledge. This implies, for example, that backup vehicles may not always be available in the case of launch failures, since failure of a single spacecraft program is not catastrophic to the extent that the remaining space program will be delayed appreciably by that failure, or that the national security is in jeopardy.

On the other hand, it is essential that NASA establish a high degree of reliability in the vehicle and spacecraft systems, since failure of one mission represents a loss of a significant fraction of the yearly effort. The NASA philosophy for obtaining high reliability can be stated as follows: *Reduce to a minimum the number of different types of vehicles, spacecraft, and components that are developed, and thereby increase the frequency with which those that remain are used.* NASA expects eventually to have available a fleet of standard vehicles and spacecraft whose reliability will more than offset the disadvantage that they may not be optimum for specific missions.

The launching vehicles which have been used or will be used are shown in Figure 7. Table 1 lists all spacecraft which have been successfully launched by both NASA and the Department of Defense, and indicates which vehicles will be used in the future for major programs. If the philosophy of minimum variety is to be followed, then the number of different types of vehicles should be reduced. This, indeed, is the trend in the long-range program. Many of the vehicles shown are interim vehicles, chosen simply because they were most readily available. They have given good service, but will be phased out in favor of a set of five or six vehicles which will provide an adequate variety of payload capabilities. The characteristics of these vehicles which NASA will retain in its vehicle program are described below (Reference 2).

Scout

The Scout is a four stage, solid propellent vehicle (Figure 8). This vehicle development program was initiated in late 1958 and the first successful launching occurred on February 16, 1961, when a balloon satellite 3.7 meters in diameter (Explorer IX) was orbited. The vehicle is expected to have a multiplicity of uses. As much as 6 kilograms can be placed into a 550-kilometer circular orbit above the earth; vertical probes carrying useful payloads to heights as great as 7500 kilometers can be launched. In addition, the

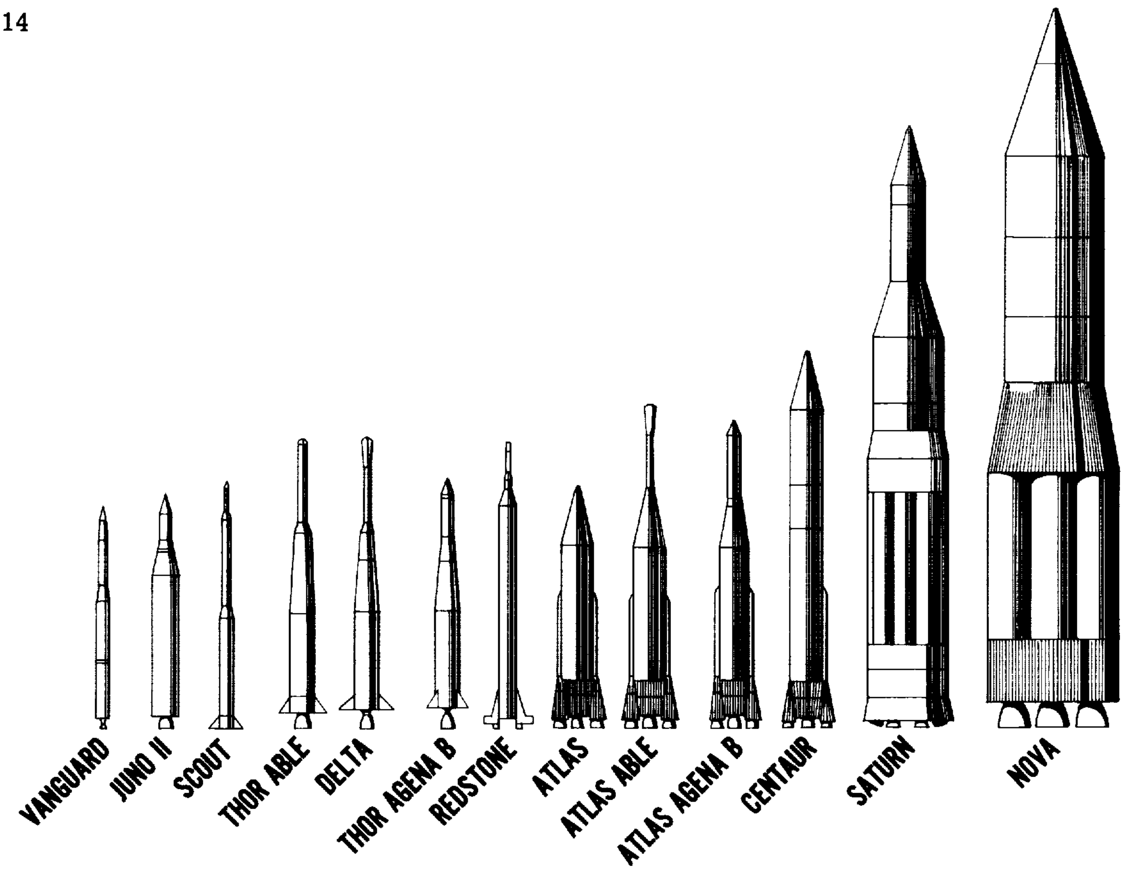

Figure 7 - The U. S. launch vehicles

Scout can be used for testing very high speed air frame designs and re-entry bodies within the atmosphere. The capability will exist for launching the Scout vehicle from the Atlantic and the Pacific Missile Ranges and from Wallops Island, Virginia. One of the principal merits of the Scout is its relatively low cost. The cost of a production vehicle plus the cost of the launching operation may be less than one million dollars. By comparison, the purchasing and launching of the Delta vehicle may cost as much as $2,500,000.

Thor-Agena B

The Thor-Agena B, as the name implies, consists of a Thor intermediate range ballistic missile (IRBM) first stage and an Agena B second stage (Figure 9). This second stage is an enlarged version of the one used successfully in the Air Force Discoverer Program. Because of the relatively high vehicle reliability achieved in the Discoverer program, NASA elected to employ the Thor-Agena B as successor to the previous IRBM-based space vehicles (e.g., Thor-Able, Delta, and Juno II). It is planned that the

Table 1

Launch Vehicle Summary

Table 1

Launch Vehicle Summary

Vehicle	Stage	Propellant	Stage Weight (Pounds)	Thrust (Pounds)	Maximum Diameter (Feet)	Height Less Payload (Feet)	Payload (Pounds)		First Launch	Spacecraft
							550-km Orbit	Escape		
Jupiter C	1 2 3 4	Lox/hydyne Solid Solid Solid	65,000	83,000	5.8	68.5	30	-	Jan. 31, 1958 (Army)	Explorer I, III, IV
Vanguard	1 2 3	Lox/ker UDMH/WIFNA Solid	17,600 4,200 430	28,000 (SL) 7,700 2,200	3.75	72	21.5 (Elliptic Orbit)	-	March 17, 1958 (Navy)	Vanguard I, II, III
Juno II	1 2 3 4	Lox/RP Solid Solid Solid	120,000 750 200 60	150,000 (SL) 15,000 4,000 1,600	8.8	77	95 (Maximum Load)	15	Dec. 6, 1958 (Army)	Pioneer III, IV, Explorer VII, VIII, XI
Thor-Able	1 2 3	Lox/RP WIFNA/UDMH Solid	107,000 4,600 525	150,000 (SL) 7,700 2,800	8	92	500	60	May 13, 1960	Pioneer I, V, Explorer VI, Tiros I, Transit 1B, 2A, 3B, Courier 1b
Atlas-Able	1 2 3 4	Lox/RP Lox/RP WIFNA/UDMH Solid	260,000 4,600 525	367,000 (SL) 80,000 7,700 2,800	10	104	-	360	No successful launches	
Delta	Nominally the same configuration and performance as Thor-Able except for a more refined guidance system.								May 13, 1960	Echo I, Tiros II, Explorer X
Scout	1 2 3 4	Solid Solid Solid Solid	23,600 9,600 2,700 525	103,000 (SL) 62,000 13,600 2,800	3.3	65	150	-	July 1, 1960	Explorer IX
Atlas	1 2	Lox/RP Lox/RP	260,000	360,000 (SL)	10	97	-	-	July 29, 1960	Score, Mercury*
Redstone	1	Lox/RP	66,000	78,000 (SL)	5.9	83	Ballistic	-	Dec. 19, 1960	Mercury
Atlas-Agena B	1 2 3	Lox/RP Lox/RP IRFNA/UDMH	260,000 14,000	367,000 (SL) 80,000 15,000	10	98	5,000	750	1961	Ranger* OAO*, OGO* Samos II**, Midas II**
Centaur	1 2 3	Lox/RP Lox/RP Lox/H_2	260,000 30,000	367,000 (SL) 80,000 30,000	10	105	8,500	2,500	1962	Mariner*, OGO*, Surveyer*
Thor-Agena B	1 2	Lox/RP IRFNA/UDMH	107,000 14,000	165,000 (SL) 15,000	8	86	1,600	-	1962	OSO*, Nimbus*, OGO*, Discoverer (I, II, V, VI, VII, VIII, XI, XIII, XIV, XV, XVII, XVIII, XIX, XX, XXI, XXIII, XXV***
Saturn (C-1)	1 2 3	Lox/RP Lox/H_2 Lox/H_2	- - -	1,500,000 (SL) 70,000 35,000	21.6	150	19,000	5,000	1961	
Saturn (C-2)	1 2 3	Lox/RP Lox/H_2 Lox/H_2	- - -	1,500,000 (SL) 800,000 70,000	21.6	-	45,000	-	1963	

*Future major programs.

**Launched by earlier Atlas-Agena, now obsolete.

***Many of the earlier Discoverer spacecraft were launched by the earlier Thor-Agena, now obsolete.

Thor-Agena B will be used for launching both meteorological and scientific (i.e., fields and particles) spacecraft. Present plans are that all of these vehicles will be launched at the Pacific Missile Range into highly inclined earth orbits.

Atlas-Agena B

The Atlas-Agena B (Figure 10) uses the same upper stage planned for the Thor-Agena B on an Atlas first stage. The Atlas-Agena B will be used in a number of Air Force programs and its basic design will have undergone a number of firings before it is used for a

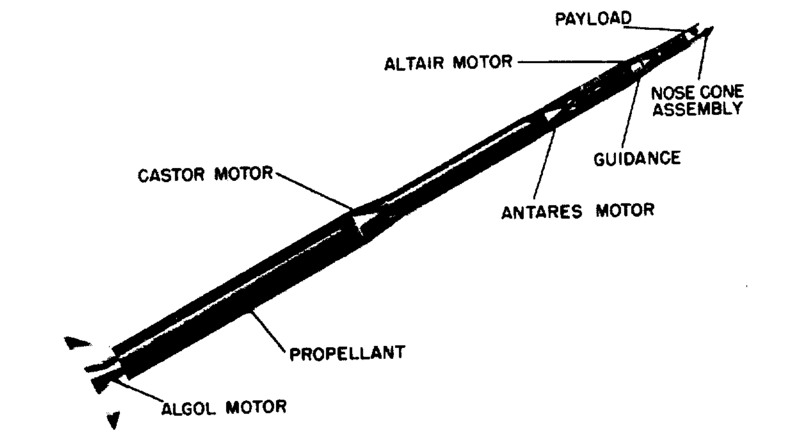

Figure 8 - The Scout launch vehicle

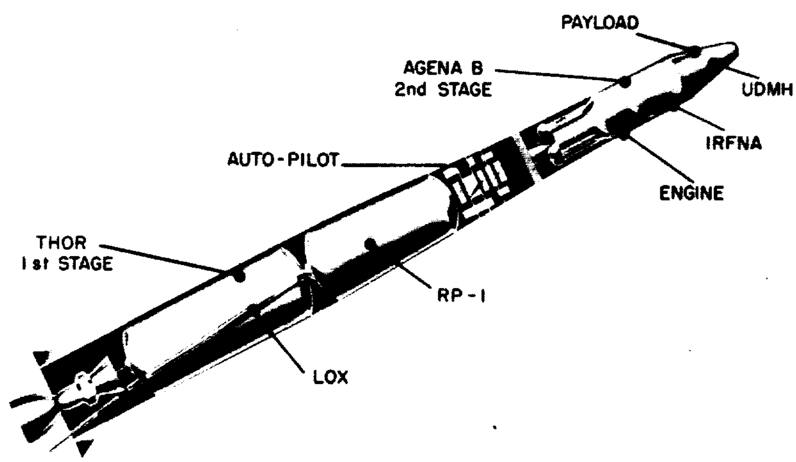

Figure 9 - The Thor-Agena B launch vehicle

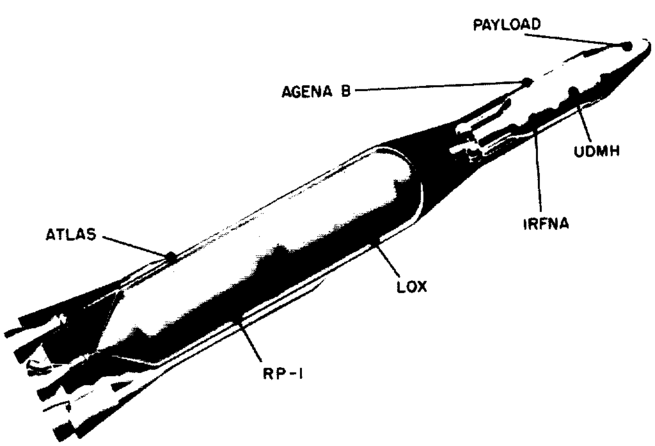

Figure 10 - The Atlas-Agena B launch vehicle

NASA mission. NASA proposes to use the Atlas-Agena B principally for early lunar exploration and scientific earth satellites. In time, the Atlas-Agena B may be replaced by the Centaur. Present plans are to launch most of the Atlas-Agena B vehicles from the Atlantic Missile Range, but a few will be launched from the Pacific Missile Range.

Centaur

The Centaur vehicle consists of an Atlas first stage and a second stage with hydrogen and oxygen propellents (Figure 11). The high-energy propellents give the Centaur the greatest capability of any Atlas-based vehicle now programmed. The engineering design of the new engine is now complete and one of these engines has been operated for more than 30 minutes at full thrust; however, a great deal of research, engineering, and developmental testing remain to be done before the first launching attempt. The inertial guidance system for this vehicle is very advanced. Centaur will be employed for a variety of scientific missions including lunar and planetary exploration and geophysical studies. According to current plans, Centaur will be launched from the Atlantic Missile Range.

Saturn

Three versions of the Saturn vehicle group are being considered: configurations C-1, C-2, and C-3. The C-1, with the least payload capability but the earliest availability, is under active development. It consists of a 1,500,000 pound thrust cluster of eight Rocketdyne engines as the booster, a second stage utilizing four Pratt and Whitney Centaur engines to provide a total thrust of 70,000 pounds, and a third stage which is essentially the existing Centaur hydrogen-oxygen rocket suitably modified for vehicle and spacecraft attachments. This Centaur engine will have a thrust of approximately 35,000 pounds.

The C-2 is presently in the planning, parameter study, and early layout phase. It will utilize the same booster and upper stages as the C-1 vehicle but with an additional stage inserted between the booster and the C-1 second stage. The additional stage of the proposed C-2 vehicle will be a completely new development, with four 200,000 pounds thrust hydrogen-oxygen engines, giving the stage a thrust of approximately 800,000 pounds. Present plans call for both the Saturn C-1 and C-2 to be launched from the Atlantic Missile Range at Cape Canaveral.

Figure 12 illustrates the manner in which the earlier vehicles will be incorporated into larger, more advanced vehicles, in keeping with the philosophy stated earlier. The C-3 configuration, which would be the largest all-chemical version of the Saturn, has not gone beyond initial conceptual planning and performance calculations. Its development depends mainly on the results of extensive studies covering the full spectrum of space flight operations with the C-2 capability.

It can be seen from the above summary that the NASA vehicle program covers the spectrum of launch vehicles - from the small and relatively inexpensive Scout to the Saturn. Preliminary planning is underway for the development of the even larger Nova vehicle. It is expected that this assortment of vehicles will be able to launch spacecraft having a wide range of configurations to accomplish a large variety of missions. The small vehicles will launch relatively short lead-time payloads for conducting exploratory experiments and for the early investigation of new phenomena. The larger vehicles will allow the simultaneous flight of a large number of related experiments for synoptic observations of the various phenomena.

THE SPACECRAFT

The philosophy outlined for the launch vehicle program also applies to the spacecraft program. The development of a relatively small number of observatory-type spacecraft designs which can be used over and over for many different experiments should result in greater reliability than individual tailoring of the spacecraft for each new launching. This philosophy applies to the programs for the technological utilization of space and for manned space flight, as well as to the unmanned scientific research program.

The unmanned scientific spacecraft program is divided into two major parts: experiments with rockets and satellites to investigate the earth and its environment; and experiments with space probes to explore the moon, the planets and interplanetary space. To accomplish the first part of this program, basic spacecraft systems and experiments are being designed for the Orbiting Solar Observatory (OSO), the Orbiting Astronomical Observatory (OAO) and the Orbiting Geophysical Observatory (OGO). It is expected that these observatories will be launched at regular intervals, carrying whatever experiments are ready at that time, into orbits determined by the experiments carried. The differences between these observatories are primarily differences between the stabilization and orientation systems. The OSO, (Figure 13), as its name implies, is designed to study the sun itself and phenomena directly related to the sun; thus, its primary orientation will be toward the sun. This spacecraft is now under construction and will weigh about 160 kilograms when completely equipped. Basically, it consists of a flywheel-like section with attached arms, which is spun to produce a large moment of inertia for gyroscopic rigidity, and a solar oriented section containing the sensors and solar battery. A compressed-gas jet system will keep the spin axis directed normal to the spacecraft-sun line, and a motor will produce a torque to maintain the rotation of the oriented section relative to the flywheel section. It is expected that orientation relative to the sun will be maintained with an accuracy better than a few minutes of arc. The first OSO launch is expected during 1962; one of the primary instruments in this spacecraft will be an ultraviolet spectrometer.

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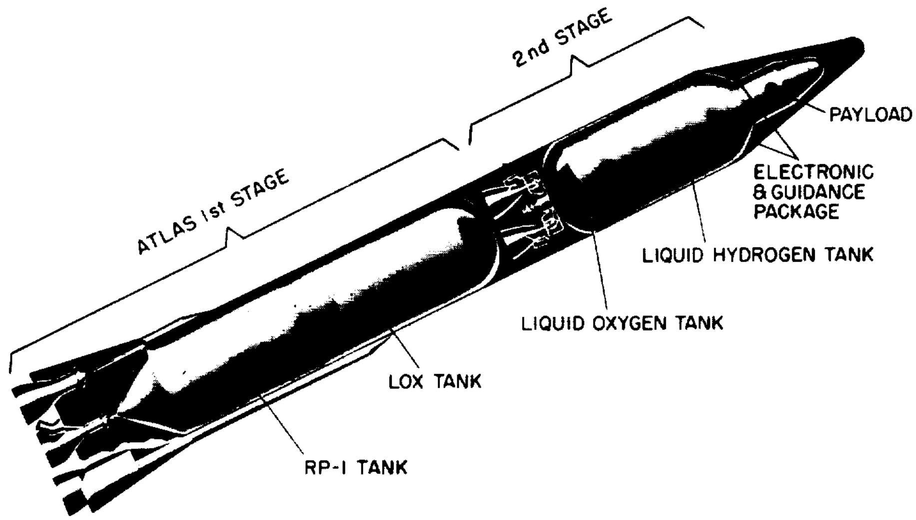

Figure 11 - The Centaur launch vehicle

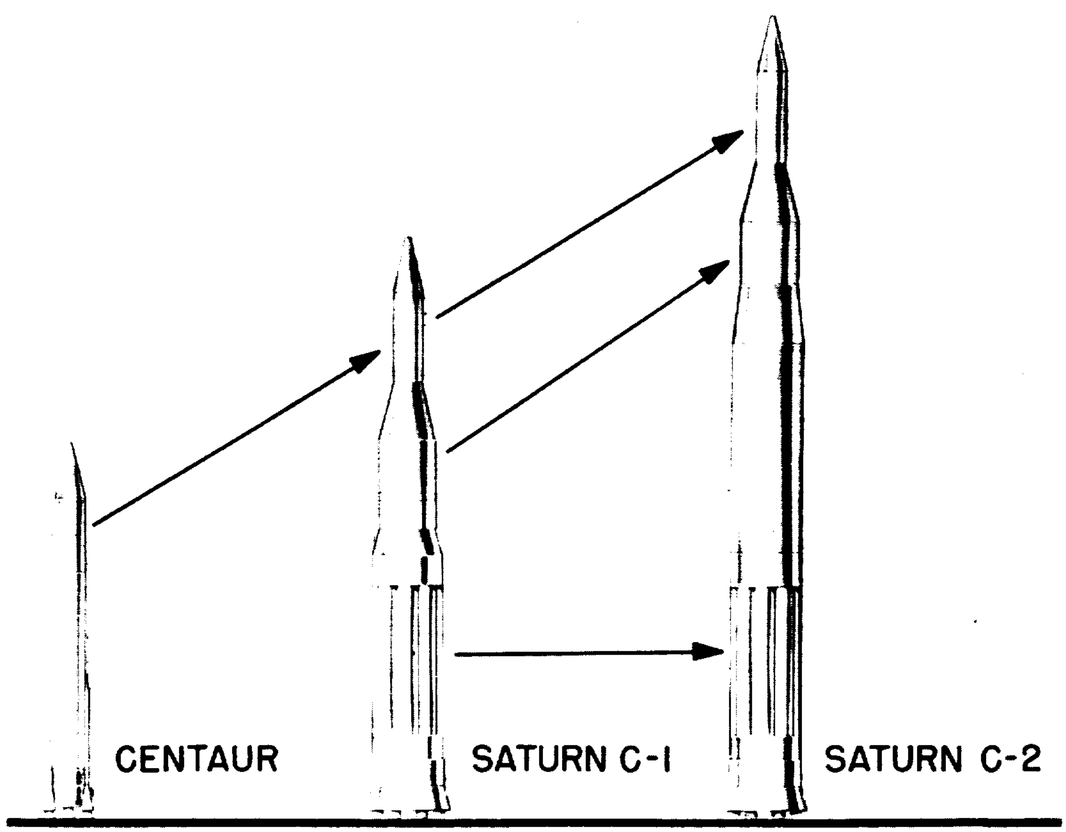

Figure 12 - Evolution of the Saturn C-2

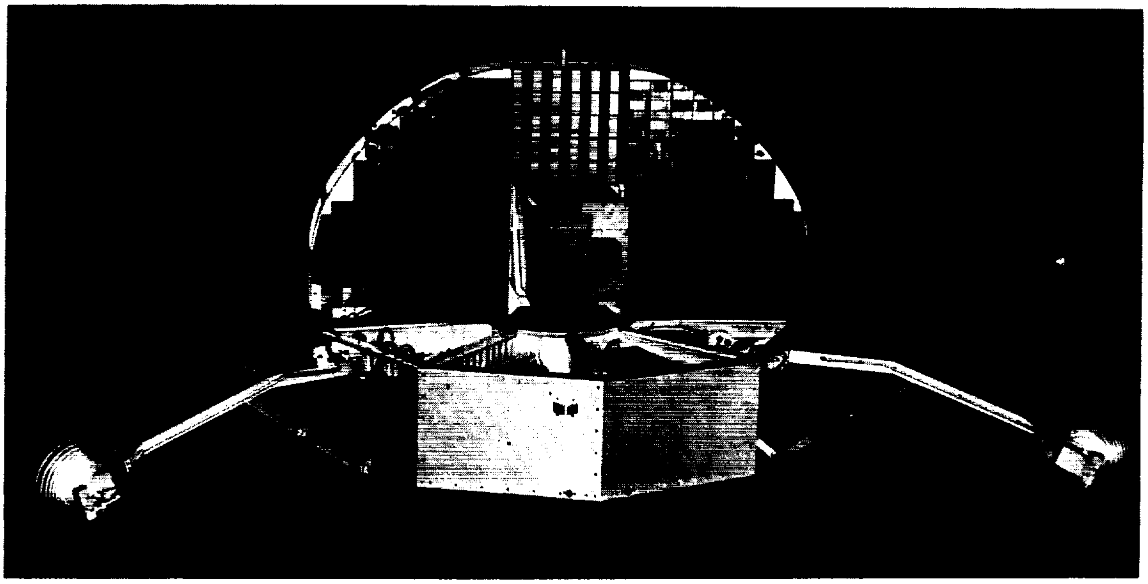

Figure 13 - The Orbiting Solar Observatory (OSO)

An artist's conception of the Orbiting Astronomical Observatory is shown in Figure 14. The length of the central body will be about 3 meters; the OAO is expected to weigh about 1600 kg. This spacecraft will have a highly precise celestial-inertial stabilization and orientation system which will aim the directional detectors in any arbitrary direction on command with an accuracy of several seconds of arc. It will be capable of carrying a telescope 0.9 meters in diameter in the main body. The main spacecraft system will include the power, telemetry, and stabilization, and the thermal control subsystems which will be used by the appropriate experiments. It is expected that many types of astronomical experiments will be flown on the OAO, including infrared, ultraviolet, radio, x-ray, gamma-ray astronomy experiments. Some of these are expected to employ photon counting techniques to obtain very high sensitivities.

The third and most universal type of large stabilized spacecraft system is the Orbiting Geophysical Observatory (Figure 15), which will carry a wide variety of experiments including those designed to investigate energetic particles, magnetic, electric, and gravitation fields, dust, atmospheric structure, the ionosphere, solar physics, astronomy, meteorology, and spacecraft technology. It is anticipated that this observatory will carry a larger proportion of particle and field experiments than the two types just described. Its primary orientation will be toward the earth but appendages will direct sensors toward the sun and in the plane of the orbit. The OGO will weigh a total of about 450 kilograms – of which at least 68 kilograms will be reserved for the experiments themselves. The standard observatory will include the power, data handling, temperature control, and stabilization subsystems which will remain essentially unchanged from mission to mission. A number of boom-like extensions will be provided to support experiments which are sensitive to the

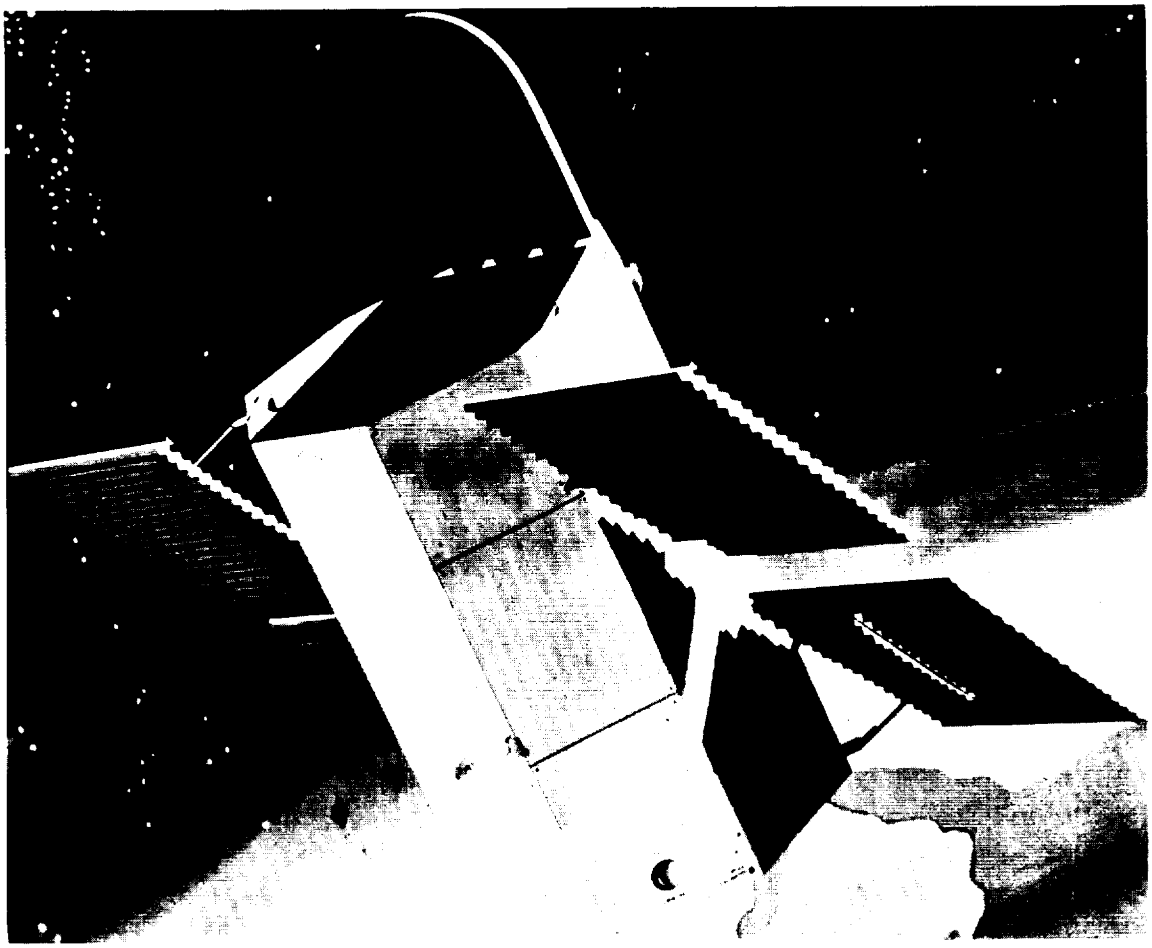

Figure 14 - The Orbiting Astronomical Observatory (OAO)

spacecraft induced environmental disturbances. It will be possible to launch the OGO spacecraft into a wide variety of orbits ranging from a low altitude (270-km perigee, near-circular) polar orbit with the Thor-Agena B launch vehicle to a high eccentricity (270-km perigee, 110,000-km apogee) 31-degree inclination orbit with the Atlas-Agena B. The first Eccentric Orbiting Geophysical Observatory (EOGO) will be launched in mid-1963, and the first Polar Orbiting Geophysical Observatory (POGO) will be launched in mid-1964.

Although an effort is being made to avoid custom design and construction for each satellite by using the standardized observatories, there will continue to be a need for tailor-made satellites for small groups of specific scientific experiments. This will be true particularly for the small Scout spacecraft on which the weight penalty for standardized design is not acceptable. The Scout will be used extensively in the very near future until the heavier and more complex observatories become available.

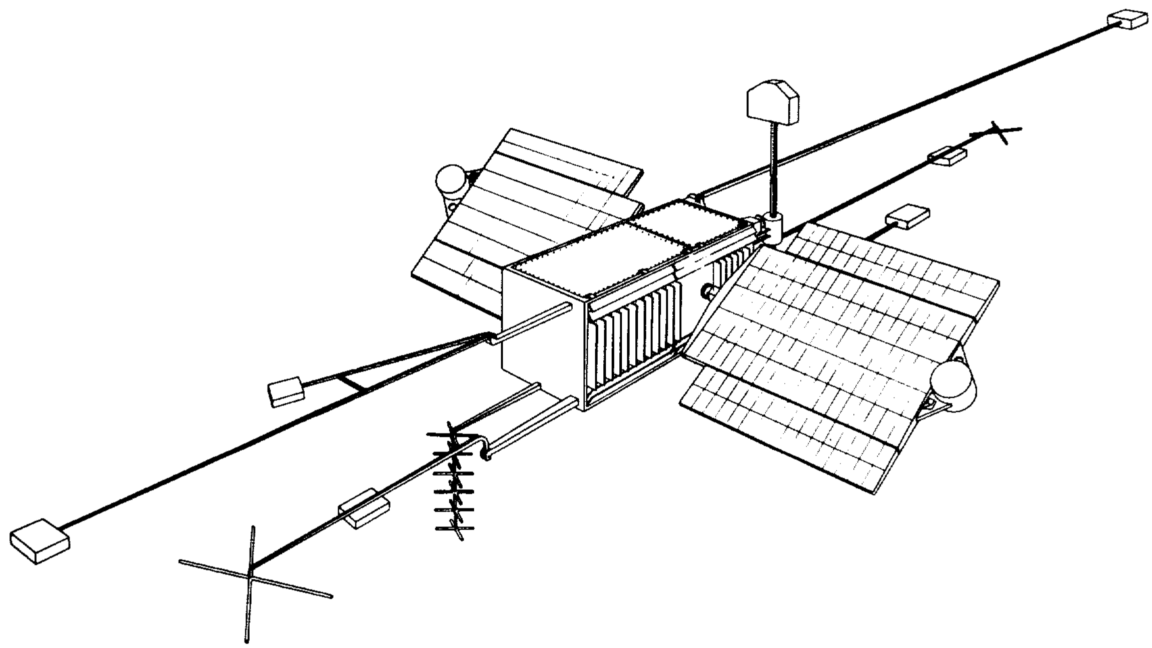

Figure 15 - The Orbiting Geophysical Observatory (OGO)

Experiments which require considerable time in interplanetary space, or which are intended to investigate the moon and planets, will be carried on one of a series of interplanetary spacecraft. The first of these is Ranger (Figure 16) which is intended for use in lunar missions with gross weights varying from 300 to 550 kilograms. The first two of this series will carry predominately energetic particles and magnetic field experiments to radial distances of 10^6 kilometers from the earth. The later lunar impact missions will use a modified version of the basic spacecraft, which will carry a survivable capsule containing a seismometer and experiments to investigate the moon's surface. During the early stages of these flights from the earth to the moon, the Ranger spacecraft will maintain three-axis attitude control with its antenna pointing toward the earth and its solar paddles directed toward the sun. Radio tracking will reveal any necessary course corrections, which the spacecraft will make on command by orienting itself for a mid-course rocket firing, and then reorienting itself as before. As the spacecraft approaches the lunar surface, it will reorient itself on command to direct its major axis parallel with the vertical descent path, and will then begin taking high resolution television pictures and performing experiments on the lunar surface. At a low altitude, the survivable capsule will be slowed by a retro-rocket for a rough but safe landing on the moon's surface, where it will perform other experiments.

Very closely related to the Ranger configuration is the Mariner spacecraft being developed for interplanetary flights to Venus and Mars. The basic spacecraft frame is nearly identical with that of the Ranger, but the solar paddles are larger and additional equipment has been included to make possible transmission from the larger distances involved. The first of these missions will be to Venus and will include a large variety of energetic particles and magnetic field experiments intended to investigate the entire charged particle energy spectrum from near thermal to high energy cosmic rays. A later mission will carry experiments to the near vicinity of the planet Mars.

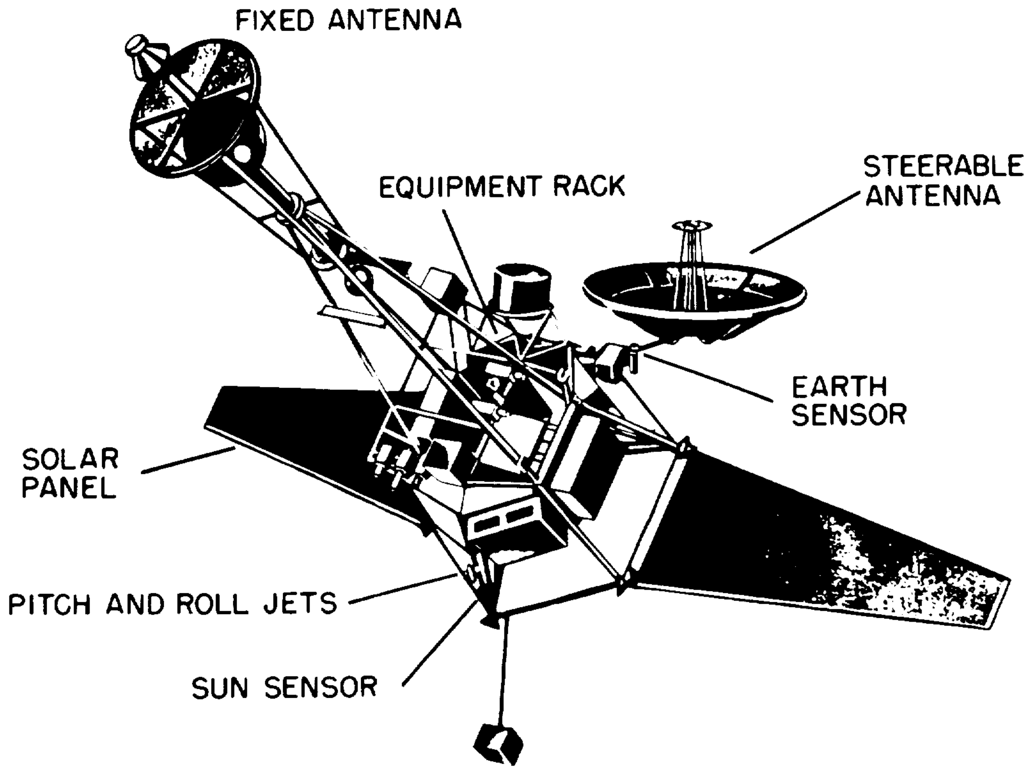

Figure 16 - The Ranger

The next program in this series will utilize the Surveyor spacecraft which will be intended to soft-land experiments on the lunar surface. It will be used primarily for analyzing the structure of the moon and the properties of its surface.

CONCLUDING REMARKS

The particles and fields space research program of NASA has been presented in relation to the launching vehicles and the spacecraft intended for use in its accomplishment. It is believed that this program will provide, within the next few years, the solutions to some of the presently existing questions and the creation of many more questions which will require answers in the search for a better understanding of our physical universe.

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